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(54) Apparatus for helical scan imaging in X-ray computed tomography

Helical Scanning Röntgen-Computertomographiegerät

Appareil d'imagerie du type à balayage hélicoidal pour tomographie par calculateur à rayons X

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(56) References cited:
EP-A- 0 113 879
EP-A- 0 383 232
EP-A- 0 405 862
EP-A- 0 450 152
US-A- 4 789 929

Description

[0001] Recently, there has been a proposition of an X-ray CT apparatus capable of carrying out a so called helical scan imaging. As shown in Fig. 1, in the helical scan imaging, a body to be examined P located on a bed plate 100 is moved along a direction of its body axis while an X-ray tube 101 and a detector 102 are rotated around the body to be examined P, such that the X-ray tube 101 moves along a helical trajectory 103 shown in Fig. 2 relative to the body to be examined P. In reconstructing the image from the data collected by such a helical scan, tomographic image data are obtained from data collected during one rotation around the body to be examined P, such as those collected between points a and b shown in Fig, 2. Such a helical scan imaging has an advantage that the three-dimensional information on the body to be examined P can be obtained in a relatively short period of time.

[0002] Now, in such a helical scan imaging, the slice plane obtained from data collected between the points a and b does not appear like a normal slice plane shown in Fig. 3A which can be obtained by the ordinary scans, but appears as shown in Fig, 3B in which 0° plane and 360° plane do not coincide with each other, so that when these data are directly used in reconstructing the image, the strong artefacts appear on the reconstructed image. For this reason, the reduction of the artefacts is achieved by deriving the data of the same single slice plane from the collected data by using the interpolation as follows.

[0003] For example, as shown in Fig. 4, the data at a point C of a desired rotational phase on a desired slice plane can be obtained by using the interpolation of the data d_A of the point A in the same rotational phase as that of the point C and on a part of the trajectory 103 neighboring the point C, and the data d_B of the point B in the same rotational phase as that of the point C and on another part of the trajectory 103 neighboring the point C. Therefore, in a case of using a linear interpolation, the data d_C at the point C can be obtained by the following expression:

$$d_C = \frac{m}{l+m} \times d_A + \frac{l}{l+m} \times d_B$$

where l is a distance between the points A and C, and m is a distance between the points B and C, as shown in Fig. 4.

[0004] Now, as shown in Fig. 5, in reconstructing the image from the data collected by the helical scan, in order to obtain the necessary data for reconstructing the image at a slice center position E, the data must be collected at least at a main data region D which covers a half rotation (180°) ahead and a half rotation (180°) behind the slice center position E in a case of a full scan.

[0005] In addition, in a case the data for reconstruction are to be derived from the collected data by using the interpolation, the data must also be collected at supplementary data regions F and G which cover a half rotation (180°) ahead and a half rotation (180°) behind the main data region D. Namely, in order to obtain the data at a point C' on the slice center position E by the interpolation, the data at a point A' in the main data region D as well as the data at a point B' in the supplementary data region F become necessary. Namely, in order to obtain the data at a point C" on the slice center position E by the interpolation, the data at a point A" in the main data region D as well as the data at a point B" in the supplementary data region G become necessary.

[0006] Therefore, the operator must position the body to be examined P and the bed plate 100 and set up the scanning region such that the scan and the data collection can be carried out for the main data region D and possibly also for the supplementary data regions F and G if necessary, according to the desired imaging regions on the body to be examined P.

[0007] Moreover, it is further preferable for the operator to position the body to be examined P and the bed plate 100 and set up the scanning region such that the scan also covers the regions for the initial acceleration and the final deceleration of the motion of the bed plate 100 along the body axis of the body to be examined P at which the data collection is unnecessary, so as to obtain the accurate data collected only while the bed plate 100 is moving at a constant speed.

[0008] However, in a conventional X-ray CT apparatus capable of carrying out the helical scan imaging, the operator must carry out the initial set up operation including the positioning of the body to be examined P and the bed plate 100 and setting up of the scanning region described above, on his own discretion, so that the these positioning and setting up operations have been cumbersome as well as not very accurate.

[0009] An apparatus according to the preamble of claim 1 is known from EP-A-0 113 879.

[0010] It is therefore an object of the present invention to provide an apparatus for a helical scan imaging in an X-ray CT, in which the initial set up operation can be achieved easily and accurately, without relying heavily on the discretion of the operator.

[0011] This object is achieved by an X-ray CT apparatus according to claim 1.

[0012] Further developments of the invention are given in the dependent claims.

[0013] Other features and advantages of the present invention will become apparent from the following description taken in conjunction with the accompanying drawings.

Fig. 1 is a front view of a main part of a conventional X-ray CT apparatus for carrying out a helical scan imaging.

Fig. 2 is a perspective view of a body to be examined, showing a trajectory of an X-ray tube around the body to be examined realizing in the helical scan

imaging.

Fig. 3A is a perspective view of a typical slice plane obtained by an ordinary scanning in an X-ray CT apparatus.

Fig. 3B is a perspective view of a typical slice plane obtained by the helical scan imaging in an X-ray CT apparatus.

Fig. 4 is a perspective view of a trajectory of the X-ray tube realizing in the helical scan imaging, for explaining the linear interpolation for deriving the data for the image reconstruction.

Fig. 5 is a side view of a trajectory of the X-ray tube realizing in the helical scan imaging, for explaining a main data region and supplementary data regions to be set up around a slice center position.

Fig. 6 is a schematic block diagram of certain aspects of an embodiment of an X-ray CT apparatus according to the present invention.

Fig. 7 is a side view of a body to be examined, showing one possible initial set up realizable in the apparatus of Fig. 6.

Fig. 8 is a side view of a body to be examined, showing further aspects of the initial set up realizable in the apparatus of Fig. 6.

[0014] Referring now to Fig. 6, certain aspects of an embodiment of an X-ray CT apparatus according to the present invention will be described in detail.

[0015] The X-ray CT apparatus 1 has a scanner unit 2 for carrying out scans with respect to a body to be examined P, including a bed plate 3 for carrying the body to be examined P along a direction of the body axis of the body to be examined P, an X-ray tube 4 for irradiating X-rays on the body to be examined P on the bed plate 3, and a detector 5 for detecting the X-rays irradiated by the X-ray tube 4 and penetrated through the body to be examined P, where the bed plate 3 is linearly movable along the direction of the body axis of the body to be examined P, while the X-ray tube 4 and the detector 5 are integrally rotatable around the body to be examined P at a predetermined constant angular speed. In this scanner unit 2, the helical scan imaging is carried out by moving the body to be examined P located on the bed plate 3 along the direction of the body axis of the body to be examined P while rotating the X-ray tube 4 and the detector 5 around the body to be examined P, such that the X-ray tube 4 moves along a helical trajectory relative to the body to be examined P.

[0016] In addition, this X-ray CT apparatus 1 further comprises a bed plate driving unit 6 for driving the bed plate 3 into the linear motion along the direction of the body axis of the body to be examined P; a bed plate controller 7 for controlling the driving operation by the bed plate driving unit 6 in order to control the linear motion of the bed plate 3 appropriately; a data collection unit 8 for collecting data concerning the X-rays detected by the detector 5; an image reconstruction unit 9 for reconstructing the tomographic images according to the data collected by the data collection unit 8; a display unit 10 for displaying the tomographic images reconstructed by the image reconstruction unit 9; a data collection controller 11 for controlling the data collection operation of the data collection unit 8 appropriately; and the input unit 12 from which an operator enters a desired scanning region, according to which the bed plate controller 7 and the data collection controller 11 control the bed plate driving unit 6 and the data collection unit 8.

[0017] In carrying out the helical scan imaging in this X-ray CT apparatus, the operator enters the desired imaging region in which the tomographic images are to be obtained for the slice planes located therein, through the input unit 12, and places the body to be examined P on the bed plate 3 such that a scan start side end of the imaging region is located at a predetermined scanning position.

[0018] Then, in accordance with the desired imaging region entered at the input unit 12, the bed plate controller 7 and the data collection controller 11 controls the bed plate driving unit 6 and the data collection unit 8 as follows.

[0019] Namely, as shown in Fig. 7, when the imaging region J is set up with respect to the body to be examined P with a scan start side end K located at the scanning position, the bed plate controller 7 automatically determines extra data regions L and R each of which includes a half main data region covering a half rotation (180°) part of a main data region for a first slice plane in the imaging region J and an associated supplementary data region covering additional half rotation (180°) adjacent to the half main data region, as well as an initial acceleration region M for accounting an initial acceleration of the bed plate 3 and a final deceleration region S for accounting a final deceleration of the bed plate 3, and controls the bed plate driving unit 6 to move the bed plate 3 in a direction opposite to a scanning direction for such a distance that a scan start side end N of the initial acceleration region M is moved to the scanning position.

[0020] Here, the extra data regions L and R and the initial acceleration region M and the final deceleration region S can be determined in advance according to the predetermined constant rotational speed of the X-ray tube 4 and the detector 5 and a linear motion characteristic of the bed plate 3.

[0021] Then, as the helical scan imaging starts, the X-ray tube 4 and the detector 5 are integrally rotated at a predetermined constant angular speed around the body to be examined P at the scanning position while the bed plate controller 7 controls the bed plate driving unit 6 to move the bed plate 3 in the scanning direction such that the scanning is carried out for the entire scanning region formed by the imaging region J, extra data regions L and R, initial acceleration region M and final deceleration region S until a scan finish side end T of the final deceleration region S stops at the scanning position.

[0022] As a result, the bed plate 3 initially accelerates

for a distance covered by the initial acceleration region M, moves at a predetermined constant linear speed through a distance covered by the extra data regions L and R and the imaging region J, and finally decelerates for a distance covered by the final deceleration region S, such that the X-ray tube 4 moves along a helical trajectory relative to the body to be examined P.

[0023] Meanwhile, when the imaging region J is set up with respect to the body to be examined P with a scan start side end K located at the scanning position, the data collection controller 11 also similarly determines extra data regions L and R as well as the initial acceleration and the final deceleration region S around the imaging region J automatically, and controls the data collection unit 8 such that the data concerning the X-rays detected by the detector 5 are collected only in the extra data regions L and R and the imaging region J. In other words, the data are collected by the data collection unit 8 between a scan start side end U of the extra data region L and a scan finish side end W of the extra data region R.

[0024] Then, the data collected by the data collection unit 8 from the extra data regions L and R and the imaging region J are fed to the image reconstruction unit 9 in which image data necessary to reconstruct the tomographic images at desired slice planes are derived by using the interpolation on the collected data, and the tomographic images at the desired slice planes are reconstructed by using the derived image data. Here, the interpolation can be achieved similarly to a conventional manner described above in the background of the invention section. The reconstructed tomographic images are then displayed on the display unit 10.

[0025] Thus, according to this embodiment, the initial set up operation for the helical scan imaging can be achieved by simply specifying the desired imaging region J at the input unit 12, so that the scanning region can be set up accurately, while reducing the burden of the operator.

[0026] In the present invention, the imaging region J is too wide to be covered by a single scan such that more than one scan is required, so that the bed plate controller 7 controls the bed plate driving unit 6 as follows.

[0027] As shown in Fig. 8, when the first scan finishes at a position X, the bed plate controller 7 determines a readjustment region Y containing another extra data region adjacent to the position X, correction data region, and another initial acceleration region, and controls the bed plate driving unit 6 to move the bed plate 3 in the direction opposite to the scanning direction for such a distance that a scan start side end Z of the readjustment region Y is moved to the scanning position, such that the next scan can be started at the scan start side end Z of the readjustment region Y.

[0028] Here, the correction data region is provided in the readjustment region Y in order to obtain additional data necessary in removing the inconsistency in the collected data due to the displacement of the slice plane caused by the physical motion of the body to be examined P during the readjustment between the successive scans. Thus, the data collected at the additional extra region and the correction data region overlap with the data collected in the previous scan, so as to enable the effective data correction for the subsequent scan. Furthermore, the readjustment may be achieved such that the data collected at a part of the main data region in the subsequent scan also overlap with the data collected in the previous scan, in order to account for the physical motion of the target portion of the body to be examined P due to breathing or some other cause occurring during the readjustment between the successive scans.

[0029] It is also to be noted that any one of the initial acceleration region M, final deceleration region S, and a supplementary data region in the the extra data regions L and R may be omitted if its omission is preferred.

[0030] Similarly, although the above embodiment has been described for a case of a full scan using a full 360° rotation of the X-ray tube and the detector around the body to be examined, the present invention is also equally applicable to an X-ray CT apparatus for carrying out a half scan in which the data for one rotation are obtained by using scans of 90° plus a fan angle on both sides of the desired image center position.

Claims

1. An X-ray CT apparatus for carrying out a helical scan imaging, comprising

   input means (12) for entering a desired imaging region (J),
   a bed plate (3) for carrying a body (P) to be examined along a direction of a body axis of the body (P) to be examined, which is linearly movable along the direction of the longitudinal axis of the bed plate (3),
   an X-ray tube (4) for irradiating X-rays on the body (P) to be examined on the bed plate (3),
   a detector (5) for detecting the X-rays irradiated by the X-ray tube (4) and penetrated through the body (P) to be examined, where the X-ray tube (4) and the detector (5) are integrally rotatable around the body (P) to be examined at a predetermined constant angular speed,
   data collection means (8) for collecting data concerning the X-rays detected by the detector (5) in the desired imaging region (J) entered by the input means (12),
   image reconstruction means (9) for reconstructing tomographic images according to the data collected by the data collection means (8), and
   bed plate control means (7) for controlling the linear motion of the bed plate (3) according to the desired imaging region (J) entered by the

input means (12) such that the bed plate (3) is linearly moved in a plurality of helical scans over a distance including the imaging region (J), which helical scans are arranged successively in the direction of the longitudinal axis, each of said scans except for the first scan including a readjustment region (Y) which overlaps with a region covered by the corresponding previous scan, **characterized in that** the control means (7) controls the bed plate (3) to move, during each scan, in a given direction along the longitudinal axis and to move, at the end of each scan except for the last scan and before the next scan begins, in the opposite direction along said longitudinal axis for a distance corresponding to the readjustment region (Y) of the next scan.

2. The X-ray CT apparatus of claim 1, wherein the distance includes an acceleration region (M) for initial acceleration of the bed plate (3).

3. The X-ray CT apparatus of claims 1 or 2, wherein the distance also includes a deceleration region (S) for final deceleration of the bed plate (3).

4. The X-ray CT apparatus of any of claims 1 to 3, wherein the readjustment region (Y) includes a further acceleration region for accelerating the bed plate (3) in the next scan.

5. The X-ray CT apparatus of any of claims 1 to 4, wherein the readjustment region (Y) includes a correction data region from which additional data are collected by the data collection means (8) for removing data inconsistencies due to readjustments between the successive scans.

Patentansprüche

1. Röntgenstrahl-CT-Vorrichtung zum Ausführen einer Bildgabe mit schraubenlinienförmiger Abtastung, mit

einem Eingabemittel (12) zum Eingeben eines gewünschten Abbildungsbereichs (J), einer Bettplatte (3) zum Transportieren eines Körpers (P), der zu untersuchen ist, entlang einer Richtung einer Körperachse des Körpers (P), der zu untersuchen ist, die linear entlang der Richtung der Längsachse der Bettplatte (3) bewegbar ist,
einer Röntgenstrahlröhre (4) zum Strahlen von Röntgenstrahlen auf den Körper (P), der zu untersuchen ist, auf der Bettplatte (3),
einem Detektor (5) zum Detektieren der Röntgenstrahlen, die durch die Röntgenstrahlröhre (4) ausgestrahlt wurden und durch den Körper (P), der zu untersuchen ist, hindurchgegangen sind, wobei die Röntgenstrahlröhre (4) und der Detektor (5) integral um den Körper (P), der zu untersuchen ist, mit einer vorbestimmten konstanten Winkelgeschwindigkeit drehbar sind,
einem Datensammelmittel (8) zum Sammeln von Daten, die die Röntgenstrahlen betreffen, die durch den Detektor (5) in dem gewünschten Abbildungsbereich (J), der durch das Eingabemittel (12) eingegeben worden ist, detektiert werden,
einem Bildrekonstruktionsmittel (9) zum Rekonstruieren von tomographischen Bildern entsprechend der Daten, die durch das Datensammelmittel (8) gesammelt worden sind, und
einem Bettplattensteuermittel (7) zum Steuern der linearen Bewegung der Bettplatte (3) entsprechend des gewünschten Abbildungsbereichs (J), der durch das Eingabemittel (12) eingegeben worden ist, derart, daß die Bettplatte (3) in einer Mehrzahl von schraubenlinienförmigen Abtastungen über einen Abstand, der den Abbildungsbereich (J) enthält, linear bewegt wird, wobei die schraubenlinienförmigen Abtastungen aufeinanderfolgend in der Richtung der Längsachse angeordnet sind, jede der Abtastungen, ausgenommen die erste Abtastung, einen Wiedereinstellungsbereich (Y), der sich mit einem Bereich, der durch die entsprechende vorhergehende Abtastung abgedeckt wird, überlappt, enthält, **dadurch gekennzeichnet, daß** das Steuermittel (7) die Bettplatte (3) zur Bewegung, während jeder Abtastung, in einer gegebenen Richtung entlang der Längsachse und zum Bewegen, an dem Ende jeder Abtastung, ausgenommen die letzte Abtastung, und bevor die nächste Abtastung beginnt, in der entgegengesetzten Richtung entlang der Längsachse über einen Abstand, der dem Wiedereinstellungsbereich (Y) der nächsten Abtastung entspricht, steuert.

2. Röntgenstrahl-CT-Vorrichtung nach Anspruch 1, bei der der Abstand einen Beschleunigungsbereich (M) für eine anfängliche Beschleunigung der Bettplatte (3) enthält.

3. Röntgenstrahl-CT-Vorrichtung nach Anspruch 1 oder 2, bei der der Abstand außerdem einen Abbremsbereich (S) für ein finales Abbremsen der Bettplatte (3) enthält.

4. Röntgenstrahl-CT-Vorrichtung nach einem der Ansprüche 1 bis 3, bei der der Wiedereinstellungsbereich (Y) einen weiteren Beschleunigungsbereich zum Beschleunigen der Bettplatte (3) in der nächsten Abtastung enthält.

5. Röntgenstrahl-CT-Vorrichtung nach einem der Ansprüche 1 bis 4, bei der der Wiedereinstellungsbereich (Y) einen Korrekturdatenbereich enthält, aus dem zusätzliche Daten durch das Datensammelmittel (8) zum Entfernen von Datenwidersprüchen aufgrund von Wiedereinstellungen zwischen den aufeinanderfolgenden Abtastungen gesammelt werden.

Revendications

1. Appareil de tomographie à rayons X assisté par ordinateur pour effectuer une imagerie par balayage hélicoïdal, comprenant

    des moyens d'entrée (12) pour entrer une région d'imagerie désirée (J),

    une plaque-lit (3) pour porter un corps (P) à examiner le long d'une direction d'un axe du corps (P) à examiner, ladite plaque-lit étant linéairement mobile le long de la direction de l'axe longitudinal de ladite plaque-lit (3),

    un tube à rayons X (4) pour irradier des rayons X sur le corps (P) à examiner sur la plaque-lit (3),

    un détecteur (5) pour détecter les rayons X irradiés par le tube à rayons X (4) et ayant pénétré à travers le corps (P) à examiner, ledit tube à rayons X (4) et le détecteur (5) étant capables de tourner de manière intégrale autour du corps (P) à examiner à une vitesse angulaire constante prédéterminée,

    des moyens de collecte de données (8) pour collecter des données concernant les rayons X détectés par le détecteur (5) dans la région d'imagerie désirée (J) entrée par les moyens d'entrée (12),

    des moyens de reconstruction d'image (9) pour reconstruire des images tomographiques en accord avec les données collectées par les moyens de collecte de données (8), et

    des moyens de commande pour la plaque-lit (7) pour commander le mouvement linéaire de la plaque-lit (3) conformément à la région d'imagerie désirée (J) entrée par les moyens d'entrée (12), de telle manière que la plaque-lit (3) est déplacée linéairement en une pluralité de balayages hélicoïdaux sur une distance qui inclut la région d'imagerie (J), lesdits balayages hélicoïdaux étant agencés successivement dans la direction de l'axe longitudinal, chacun desdits balayages, à l'exception du premier, incluant une région de réajustement (Y) qui chevauche une région couverte par le balayage précédent correspondant,

    caractérisé en ce que les moyens de commande (7) commandent la plaque-lit (3) afin de se déplacer, pendant chaque balayage, dans une direction donnée le long de l'axe longitudinal, et de se déplacer, à la fin de chaque balayage, à l'exception du dernier balayage et avant que commence le balayage suivant, dans la direction opposée le long dudit axe longitudinal sur une distance qui correspond à la région de réajustement (Y) du balayage suivant.

2. Appareil de tomographie à rayons X assisté par ordinateur selon la revendication 1, dans lequel la distance inclut une région d'accélération (M) pour l'accélération initiale de la plaque-lit (3).

3. Appareil de tomographie à rayons X assisté par ordinateur selon l'une ou l'autre des revendications 1 et 2, dans lequel la distance inclut aussi une région de décélération (S) pour la décélération finale de la plaque-lit (3).

4. Appareil de tomographie à rayons X assisté par ordinateur selon l'une quelconque des revendications 1 à 3, dans lequel la région de réajustement (Y) inclut une autre région d'accélération pour accélérer la plaque-lit (3) dans le balayage suivant.

5. Appareil de tomographie à rayons X assisté par ordinateur selon l'une quelconque des revendications 1 à 4, dans lequel la région de réajustement (Y) inclut une région de données de correction depuis laquelle sont collectées des données additionnelles par les moyens de collecte de données (8) pour supprimer des incohérences de données dues à des réajustements entre les balayages successifs.

FIG. 1

PRIOR ART

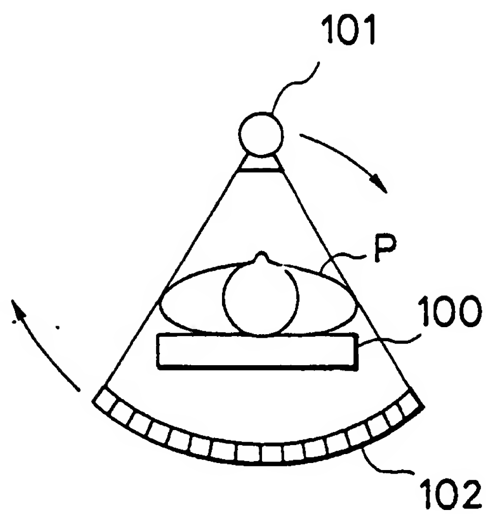


FIG. 2

PRIOR ART

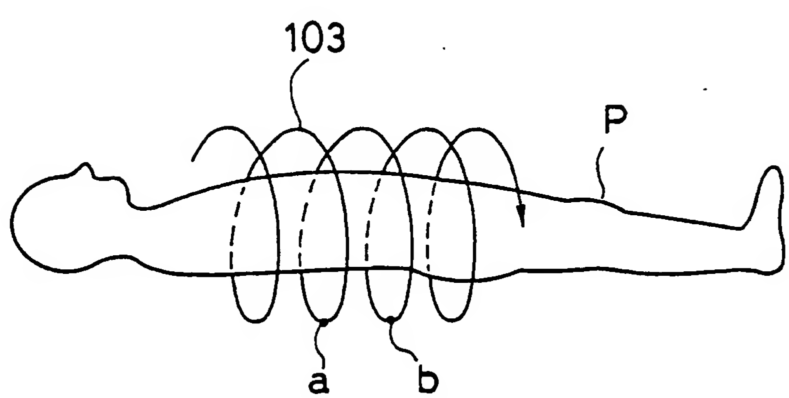


FIG. 3A
PRIOR ART

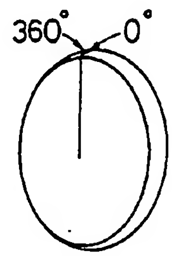


FIG. 3B
PRIOR ART

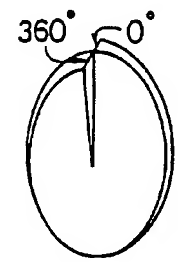


FIG. 4
PRIOR ART

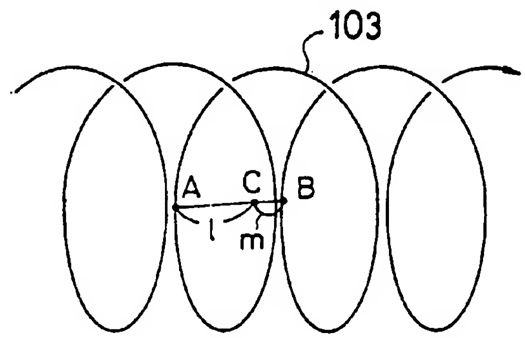
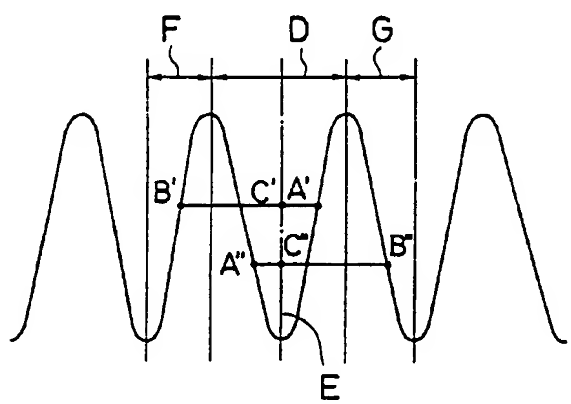


FIG. 5
PRIOR ART



F I G. 6

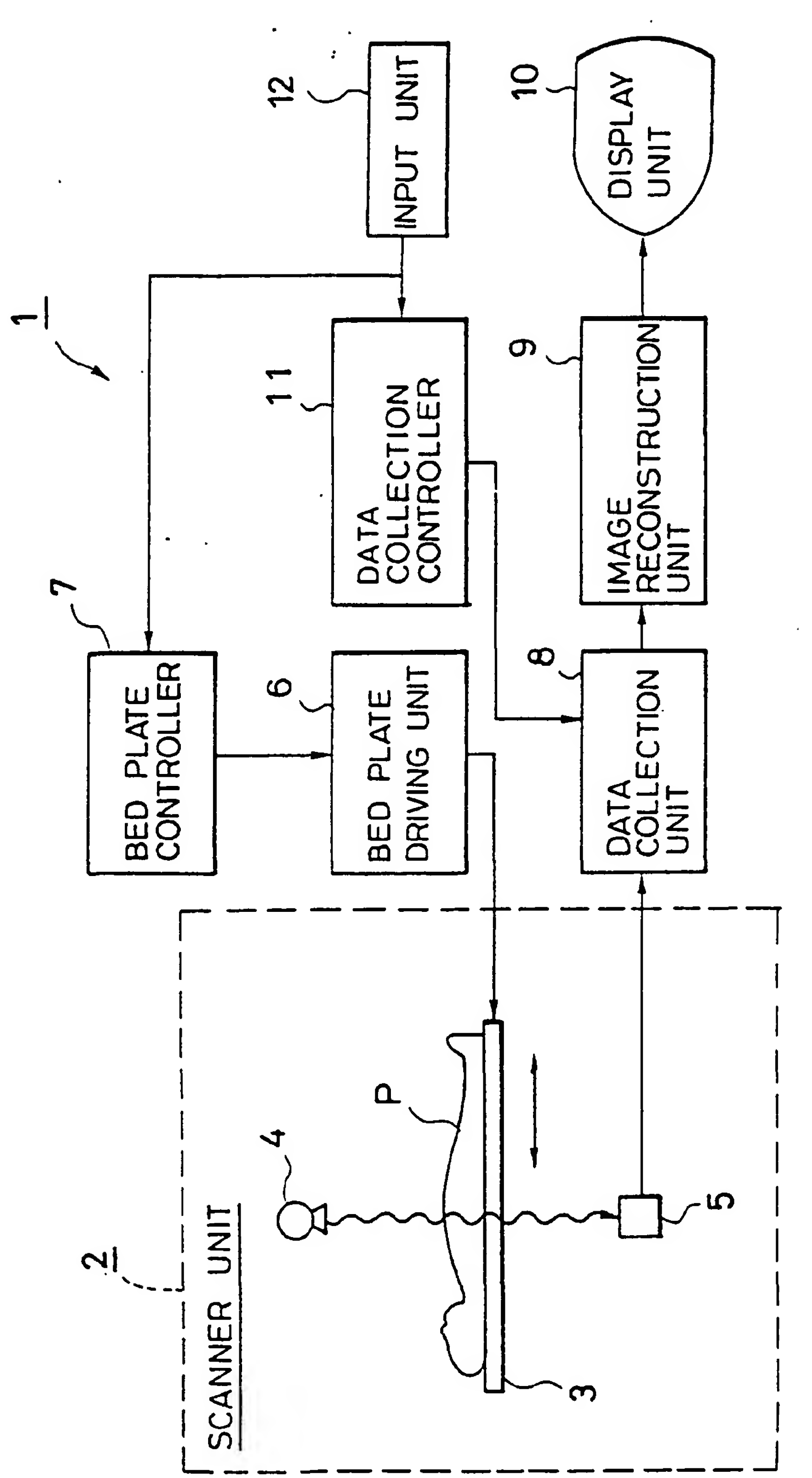

1
2
SCANNER UNIT
3
4
5
P
6
BED PLATE DRIVING UNIT
7
BED PLATE CONTROLLER
8
DATA COLLECTION UNIT
9
IMAGE RECONSTRUCTION UNIT
10
DISPLAY UNIT
11
DATA COLLECTION CONTROLLER
12
INPUT UNIT

FIG. 7

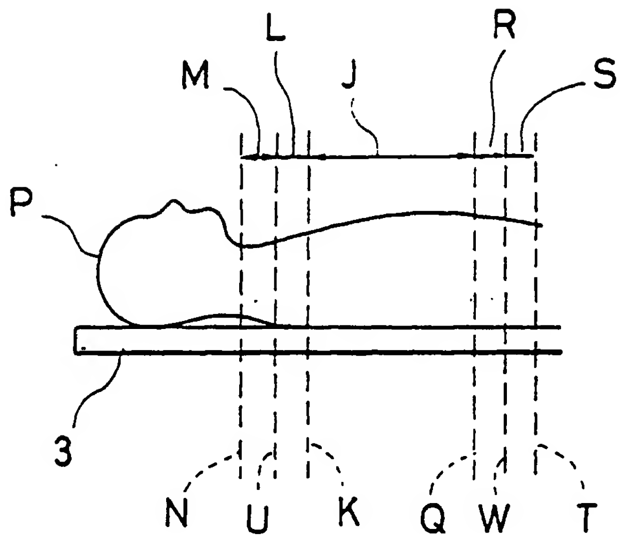


FIG. 8